CSE 310

YACC (or Bison)

YACC, Bison

- **Y**et **A**nother **C**ompilers **C**ompiler
- Unix utility that parses a token stream produced by lex according to specified LALR(1) context free grammar
- We will use **Bison** which is YACC compatible

How to use YACC

$$\begin{tikzcd}
\text{MyParser.y} \arrow[d] \\
\boxed{\text{YACC/Bison}} \arrow[d] \\
\text{y.tab.c} \arrow[d] \\
\boxed{\text{gcc}} \arrow[d] \\
\text{a.out}
\end{tikzcd}$$

yacc file containing grammar rules

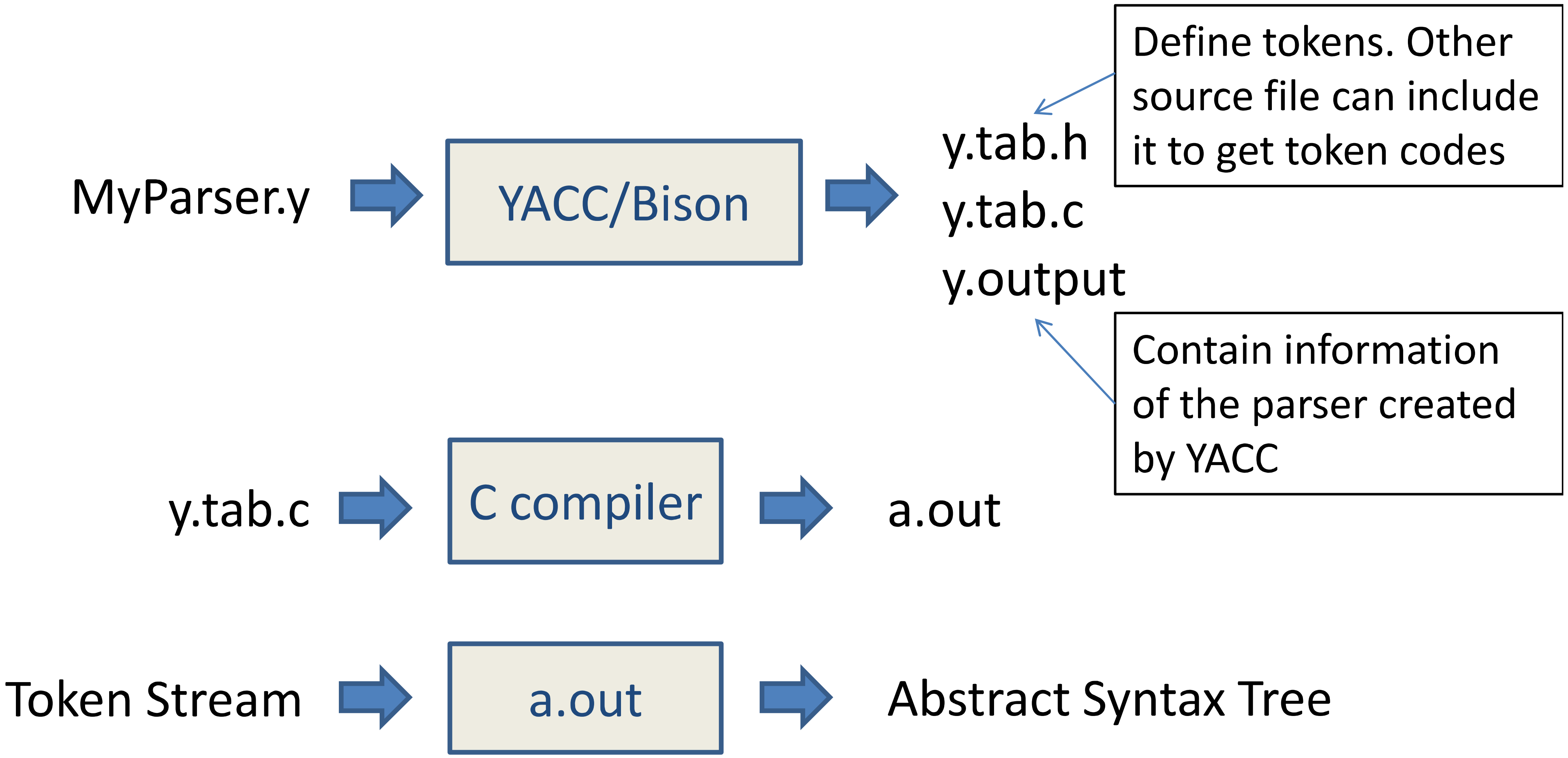
Yacc or Bison program

Parser source code created by yacc
Contains a `yyparse()` function which is invoked to do the parsing task.

C compiler

Executable program to parse according to grammar given in Myparser.y

How to use YACC


MyParser.y
YACC/Bison
y.tab.h
y.tab.c
y.output
Define tokens. Other source file can include it to get token codes
Contain information of the parser created by YACC
y.tab.c
C compiler
a.out
Token Stream
a.out
Abstract Syntax Tree

Basics: How Bison Works?

- Perform Shift/reduce parsing
  - So that’s bottom-up parsing?
- Maintains set of states, reflecting one or more partially parsed rules
- After reading a token it may take two possible actions
  - **Shift:** If the token cannot complete any rule, shift the token in internal stack
  - **Reduce:** If a rule can be completed, then pop all R.H.S. symbol from the stack and push L.H.S. symbol

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
stack:

<empty>
```

```
input:
a = 7; b = 3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

SHIFT!

```
stack:

NAME
```

```
input:
= 7; b = 3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
SHIFT!
```

```
stack:
NAME '='
```

```
input:
7; b = 3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

SHIFT!

```
stack:
NAME '=' 7
```

```
input:
; b = 3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt

    | NAME '=' exp


exp: exp '+' exp

   | exp '-' exp

   | NUMBER
```

```
REDUCE!
```

```
stack:

NAME '=' exp
```

```
input:
; b = 3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
REDUCE!
```

```
stack:
stmt
```

```
input:
; b = 3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
SHIFT!
```

```
stack:
stmt ';'
```

```
input:
b = 3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
SHIFT!
```

```
stack:
stmt ';' NAME
```

```
input:
= 3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
SHIFT!
```

```
stack:
stmt ';' NAME '='
```

```
input:
3 + a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
SHIFT!
```

```
stack:
stmt ';' NAME '=' NUMBER
```

```
input:
+ a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp


exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
REDUCE!
```

```
stack:
stmt ';' NAME '=' exp
```

```
input:
+ a + 2
```

Shift and reducing

```
stmt: stmt ‘;’ stmt
    | NAME ‘=‘ exp

exp: exp ‘+’ exp
   | exp ‘-’ exp
   | NUMBER
```

```
SHIFT!
```

```
stack:
stmt ‘;’ NAME ‘=‘ exp ‘+’
```

```
input:
a + 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
SHIFT!
```

```
stack:

stmt ';' NAME '=' exp '+'
NAME
```

```
input:
+ 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
REDUCE!
```

```
stack:
stmt ';' NAME '=' exp '+'
exp
```

```
input:
+ 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
REDUCE!
```

```
stack:

stmt ';' NAME '=' exp
```

```
input:
+ 2
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
SHIFT!
```

```
stack:
stmt ';' NAME '=' exp '+'
```

```
input:
2
```

Shift and reducing

```
stmt: stmt ';' stmt
     | NAME '=' exp

exp: exp '+' exp
    | exp '-' exp
    | NUMBER
```

```
SHIFT!
```

```
stack:

stmt ';' NAME '=' exp '+'
NUMBER
```

```
input:
<empty>
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

REDUCE!

```
stack:
stmt ';' NAME '=' exp '+'
exp
```

```
input:
<empty>
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

REDUCE!

```
stack:
stmt ';' NAME '=' exp
```

```
input:
<empty>
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

REDUCE!

```
stack:
stmt ';' stmt
```

```
input:
<empty>
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

```
REDUCE!

stack:

stmt

input:
<empty>
```

Shift and reducing

```
stmt: stmt ';' stmt
    | NAME '=' exp

exp: exp '+' exp
   | exp '-' exp
   | NUMBER
```

DONE!

```
stack:

stmt
```

```
input:
<empty>
```

How parser get Tokens?

- We constructed lexical analyzer that generate tokens!
- So somehow our parser should communicate with scanner!

Scanner Parser Interaction

- Parser assumes the existance of `yylex()` function
- This is called by `yyparse()`
- But how they agree on Token names?

Scanner Parser Interaction

- Parser assumes the existance of `yylex()` function
- This is called by `yyparse()`
- But how they agree on Token names?
  - Define token names in YACC program.
  - If you compile using “yacc –d” or “bison –d”, it will produce a y.tab.h file
  - This contains an enumeration of token definition
  - Include this y.tab.h file in your lex source file

Scanner Parser Interaction

- With each token scanner can send some value associated with it using global variable `yylval`.
- Default type is `int`
- You can redefine its type
  - We will see example
- `yytext` is also available to your parser

YACC file format

- An yacc file has **.y** extension
- Three Sections.

```
/**** Definition Section ******/
%%
/**** Rules Section ********/
%%
/**** User SubRoutines *******/
```

- Looks Familiar??

Definition Section

- Any code within %{ and %} is copied in the output file of yacc program.
- Name of the tokens (%token)
- Associativity and precedence rules (%left, %right, %nonassoc)
- Name of the start symbol (%start)
- Data type of value associated with each token (%union)
- Several other things

Definition Section

```
%{
#include <stdio.h>
#include <stdlib.h>
%}
%token ID NUM
%type variable
%start expr
```

Terminal

Non Terminal

Rules Section

- Grammar rules and corresponding actions in C code.

```
expr : expr '+' term     { $$ = $1 + $3; }
     | term              { $$ = $1; }
     ;
term : term '*' factor   { $$ = $1 * $3; }
     | factor            { $$ = $1; }
     ;
factor : '(' expr ')'    { $$ = $2; }
       | ID
       | NUM
       ;
```

User Subroutine Section

- C codes copied directly in the `y.tab.c` file
- Usually contains user defined main function
- Call **`yyparse()`** from main function

Token

- In yacc file token defintions:

```
%token NUM
```

- In y.tab.h file:

```
#define NUM 258
```

- The lex file can return NUM
- Definitions usually starts from 258 in y.tab.h

yylval

- Global variable that can be used to return some values along with token
- Declare it in lex file
- Data type is `YYSTYPE` which is defined as `int` by default
- Lex Program:

```
extern int yylval;
%%
[0-9]+    { yylval= atoi(yytext);
            return NUM;
          }
```

yylval

- If different token requires different values, you can define a union in yacc file and associate appropriate values for a Token

- Use `union`

- See an example!

Precedence & Associativity

```
%left '+', '-'
%left '*', '/'
%nonassoc UMINUS
%%
expr : expr '+' expr                {$$=$1+$2;}
     | expr '-' expr                {$$=$1-$2;}
     | expr '*' expr                {$$=$1*$2;}
     | expr '/' expr                {$$=$1/$2;}
     | '-' expr %prec UMINUS        {$$=-$2;}
     | NUM                          {  }
```

Accessing Value Stack

- We can use $ to access value returned by lex

```
expr: expr '+' expr   {$$=$1+$2;}
    | expr '-' expr   {$$=$1-$2;}
    | expr '*' expr   {$$=$1*$2;}
    | expr '/' expr   {$$=$1/$2;}
    | '-' expr        {$$=-$2;}
    | NUM             { }
```

Recursive Grammar

- Left recursion

```
list:
     item
    | list ',' item
    ;
```

- Right recursion

```
list:
     item
    | item ',' list
    ;
```

- YACC, Bison prefers left recursion. Why?

Conflicts

- Conflicts arise when there is more than one way to proceed with parsing.

- Two types:
  - shift-reduce [default action: *shift*]
  - reduce-reduce [default: *reduce with the first rule listed*]

Conflicts

- Reduce/Reduce Conflict:

```
A : B | C
B : 'X'
C : 'X'
```

- Shift/Reduce Conflict:

```
Stmt: IF '(' exp ')' stmt
    | IF '(' exp ')' stmt else stmt
```

Handling Conflicts

- See the `y.output` file for conflict details
- Think out why conflict occurred
- Rewrite grammar accordingly

`int yyparse()`

- Called once from `main()`
- Repeatedly calls `yylex()` until done:
  - On syntax error, calls `yyerror(char *s)`
  - Returns 0 if all of the input was processed;
  - Returns 1 if aborting due to syntax error.

Error Reporting

- Define the `yyerror(char *)` function
- Setting '%error-verbose' in definition section can produce more information about error

Error Handling

- The “token” ‘**error**’ is reserved for error handling:
  - can be used in rules;
  - suggests places where errors might be detected and recovery can occur.

Example:

```
stmt  : IF '(' expr ')' stmt
      | IF '(' error ')' stmt
      | FOR …
      | …
```

Error Handling

When an error occurs, the parser:

- pops its stack until it enters a state where the token 'error' is legal;
- then behaves as if it saw the token 'error'
    - performs the action encountered;
    - resets the lookahead token to the token that caused the error.

- If no 'error' rules specified, processing halts.

YACC Declaration Summary

`%start'

Specify the grammar's start symbol

`%union'

Declare the collection of data types that semantic values may have

`%token'

Declare a terminal symbol (token type name) with no precedence or associativity specified

`%type'

Declare the type of semantic values for a nonterminal symbol

YACC Declaration Summary

`%right'

Declare a terminal symbol (token type name) that is right-associative

`%left'

Declare a terminal symbol (token type name) that is left-associative

`%nonassoc'

Declare a terminal symbol (token type name) that is nonassociative (using it in a way that would be associative is a syntax error, ex: x *op*. y *op*. z is syntax error)

Reference

- Flex & Bison by John Levine
- Lecture on YACC by Tanvir Ahmed Khan
- Powerpoint slide from

  www.csie.ntu.edu.tw/~b92006/**YACC**-present-2005.**ppt**
- Powerpoint slide from

  www.cs.arizona.edu/~debray/Teaching/CSc453/DOCS/**yacc**%20tutorial.**ppt**

Thank You!